WHITE PAPER

GOING BEYOND THE CURB:

POLICIES AND BEST PRACTICES

Barbara Jacobson, CALSTART
Dan Welch, CALSTART
Lily Paul, CALSTART
James Huang, CALSTART

August 2021

This work was conducted with generous support from FedEx Cares

ACKNOWLEDGEMENTS

The authors would like to recognize the support of CALSTART staff member Emily Varnell for their critical review of and additions to this report. All findings and recommendations within this report, unless otherwise cited, are that of the authors. Any errors are the authors' own.

CALSTART
www.CALSTART.org
@CALSTART

TABLE OF CONTENTS

LIST OF ACRONYMS

AV	Autonomous Vehicle
BID	Business Improvement District
BRT	Bus Rapid Transit
CBD	Central Business District
CSM	Curb Space Management
DCFC	Direct Current Fast Charging
DOT	Department of Transportation
DPW	Department of Public Works
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
GHG	Greenhouse Gas
ICE	Internal Combustion Engine
LADOT	Los Angeles Department of Transportation
LEZ	Low Emission Zone
MBTA	Massachusetts Bay Transportation Authority
NYC	New York City
NYC DOT	New York City Department of Transportation
PBL	Protected Bike Lane
PUDO	Pick-Up and Drop-Off
TMP	Transportation Management Plan
TNC	Transportation Network Company
RFP	Request for Proposal

SFMTA	San Francisco Municipal Transportation Agency
UCC	Urban Consolidation Center
ULEZ	Ultra-Low-Emission Zone
VMT	Vehicle Miles Traveled
ZE	Zero-Emission
ZEV	Zero-Emission Vehicle

FIGURES AND TABLES

FIGURES

TABLES

EXECUTIVE SUMMARY

During the past decade (2010-2020), there has been a dramatic growth in online retail deliveries, resulting in direct doorstop deliveries to more residential areas which expand traditional freight models. Traditional commercial freight centers may not be able to meet the load growth quickly and sufficiently, and more residential areas are not properly designed to support larger capacity or zoned for commercial freight activities. Simultaneously, the disruption that the COVID-19 global pandemic caused in urban systems exposed the need for better management of the curb spaces that city residents share with the transportation and freight systems. During the peak of the pandemic, municipalities and businesses adapted to the changing rules and regulations based on public health guidelines. Curbs and streets quickly became restaurants, small gardens, fitness zones, and other outlets for residents to enjoy outdoor spaces safely and comfortably. The confluence of fluctuating goods movement and greater public demand for public space require a new, shared understanding of the street curb, where freight systems safely meet the residents and businesses that they serve.

Dynamic curb management practices that welcome new technologies while recognizing residents' needs maximize the value of the curb space and benefit all parties through enhanced efficiency, access, and safety.

- **Efficiency:** Congested roadways and overcrowded curbs create traffic, increase the costs of doing business, and increase greenhouse gas emissions. Roads and curbs that are overcrowded inhibit freight operators from completing timely deliveries. Consequently, delivery drivers may incur parking citations if they cannot legally park to complete their deliveries in allocated parking spots. The added traffic also produces inefficiencies for commuting residents, wasted personal time, and potentially expensive opportunity costs due to additional hours spent commuting.
- **Access:** Inefficient curb management often results in large vehicles clogging up streets and curbs for extended periods of time. These vehicles may cut off access to the livable spaces and public right-of-way. Improved curb management will free up space beyond loud, large freight vehicle purposes. Smaller, more sustainable vehicles can be used to meet both the needs of delivery companies and residents. Increased access also generates novel opportunities for new, dynamic goods movement companies that can meet the increasingly diverse needs of urban customers.
- **Safety:** Traditional freight systems, when combined with overcrowded streets and curbs, can create tremendous hazards for residents. Pedestrians and cyclists are more likely to be injured in collisions with large vehicles, and their movement may be blocked by trucks double parked or occupy bicycle lanes. These large vehicles also emit dangerous compounds, such as particulate matter. Enhanced systems encouraging smaller vehicles that open road access and use degrees of enhanced or autonomous detection are likely to create safer spaces for urban residents. Likewise, curbs that are open and accessible help keep residents safely on sidewalks, away from trip hazards, and free to enjoy their city.

This report recognizes two clear and opportune pathways to ushering in the benefits of dynamic curb management. New technologies that alleviate traditional freight pinch points and supportive policies that enable these technologies will create new opportunities to develop and safeguard cleaner, more efficient cities.

- **Technologies:** Advancements in battery and autonomous technologies mean that freight systems do not need to be composed of large truck fleets in all circumstances. Battery technologies have been applied to multiple vehicle types that can cleanly and reliably power smaller vehicles in crowded environments. Notably, e-cargo bikes and e-pallets combine existing technologies with the power stored in batteries to allow more efficient goods movement without relying on large trucks. Similarly, automated vehicles can reduce costs and reliably transport goods in public spaces with an even smaller footprint that does not rely on driver oversight. These technologies can reliably improve the experiences of municipal staff and residents by transitioning from traditional freight practices, unclogging streets, and reducing pollution impacts on public health.
- **Policies:** New technologies will likely require supportive policies that enable operations in city streets and on curbs where residents interact with freight systems. Freight operators are continually innovating with systems and technological improvements to reduce costs and improve performance, but the pace of technological growth has challenged some city planners that are considering best management practices to ensure that the new technologies are safely and equitably introduced. Unlocking the benefits of safer, more efficient technologies will require city planners to collaborate with industry to define how these technologies will be applied, identify how and when the technologies will be introduced into cityscapes, and work with city residents and industry partners to monitor progress, performance, and satisfaction.

SECTION I

I. CURB SPACE MANAGEMENT: THE CURRENT LANDSCAPE

Public street space demands are changing due to behavioral trends such as working from home, increased reliance on delivery of essential goods, and the reallocation of street space for people-centric transportation and recreation. During the COVID-19 global pandemic, people adapted to temporary measures and adaptive street space use, including outdoor dining, Slow Streets, and flexible and short-term loading zones. These interim steps have the potential to become permanent with municipal policies and with partners such as business owners, patrons, delivery companies, and community residents. The pandemic demonstrated the role curb space plays in the successful movement of people and goods. Harnessing the economic potential of effective curb space management through policies and best practices has broad implications on the public and private sectors, such as right-sizing fleets for last-mile delivery, reducing greenhouse gas (GHG) emissions, and developing complementary policies to support innovative last-mile delivery solutions.

ROLE OF CURB SPACE IN CITIES TODAY

A critical component of urban design, curb space delineates the point on roadways that is allocated to pedestrian movements, separated from faster moving vehicles: cars, trucks, buses, vans, and human-powered modes such as bikes and scooters. The primary uses of curb space are public transit bus loading/disembarking, parking of personal vehicles, delivery vehicle loading/unloading, and, in some municipalities, docked bikeshare stations and specific parking zones for shared micromobility.

Conventional signage adjacent to roadways, as seen in **Figure 1**, is focused on rules for stopped vehicles with day of week and time of day dictating the parking guidelines. The text-heavy signage can be confusing, and there is opportunity to streamline this signage by making it more visual with graphics and QR codes for scanning with smartphones. Pivoting away from static signage to managing curbs through digital asset management platforms will create flexible, responsive, and on-demand spaces for a variety of uses ranging from curbside pickup, outdoor dining, and

Figure 1. Parking Signage

Photo of parking signage in Brentwood, CA (2021) loading/unloading package staging areas.

Both the public and private sectors are turning their attention towards the curb: examples include the cities of Santa Monica and San Francisco, California, and private sector companies such as Lacuna, who focus on gathering data digitally about how the curb is utilized. Taking a data-driven approach about how the physical curb and street space are used supports the development of policies and ordinances making pilot programs permanent and embedding better curb space management practices in commercial loading zones and beyond. A key benefit of clean data is the digitization of curb management, allowing the public sector to make data-informed policy decisions to kick inefficiencies to the curb.

Implementing data-gathering systems requires cross-departmental coordination within municipalities and with external partners such as transit agencies and members of the public. For example, the transportation department will need to work with legal, parking, and enforcement departments and coordinate with the disability advisory board. Coordination will then happen with transit agencies for bus service operations, all with sustained outreach throughout with property owners adjacent to the curb. Privacy concerns arise with the placement of cameras, so consideration about not gathering sensitive information such as license plates is an important component of implementing digital curb space management infrastructure on public right-of-way.

The COVID-19 global pandemic accelerated market trends and online purchasing patterns drastically. Product delivery via online and in-app ordering for doorstop delivery increased so dramatically due to stay-at-home orders and social distancing practices and requirements that companies met projections set for years out. The combined revenue from the top four food delivery apps in the United States more than doubled between Quarter 2 of 2019 and Quarter 3 of 2020 (Sumagaysay, 2020), Amazon doubled its profits going into July 2020 (Selyukh, 2020), and many delivery services struggled to keep up with the increased demand (Baertlein, 2020). Given the upsurge in grocery, food, pharmacy, and goods delivery, the number of delivery vehicles operating on the roadways grew significantly. Specifically, "in 2019, eMarketer predicted that e-commerce sales would make up 22% of total retail sales by the year 2023. Now, Adobe predicts that two years' worth of anticipated e-commerce growth will take place just over the 2020 holiday season" (Mathradas, 2020). As the data indicate, the trends associated with online ordering, doorstop delivery and quick turnaround times for delivery of goods are here to stay.

To deal with the changing needs associated with expanded deliveries and decrease in typical travel and shopping during the pandemic, municipalities took creative policy and programmatic approaches to reallocate street and curb space to adapt to the changing environment. Such approaches included the implementation of Slow Streets programs to encourage people to use roadways for exercise and recreation, the conversion of parking spaces to parklets for outdoor dining and smart loading zones, specific permitting for short-term curbside pick-up, and adaptive demand pricing. The innovative approaches municipalities implemented set forth a sea of change in bringing attention to curb space management as a powerful tool.

As of the time of this paper’s publication, a handful of cities in the United States developed pilot programs focused on leveraging curb space with goods movement. The first is the City of Santa Monica, California, that launched and tested a pilot Zero Emission (ZE) Delivery Zone with intra-agency coordination among a variety of departments such as parking, legal, and accessibility. The signage in the pilot ZE Delivery Zone included QR codes for residents and users to scan the signage with smartphones to learn more about the pilot and what it means for commercial drivers as well as for public parking. Another example is a partnership with a variety of organizations such as Coaster Cycles (company focused on last-mile solutions and manufacturer of cargo e-bikes), BrightDrop (company focused on innovative last-mile delivery solutions), and the University of Washington's Urban Freight Lab to launch a micro delivery hub in Seattle, Washington (Schubert, 2021).

Pre-Existing Uses of Curb Space

While curb space has recently become an important topic, several pre-existing uses for curb space are already in place that make cities and towns function, as seen in **Figure 2**. Some examples include:

- Public transit bus stops and Bus Rapid Transit (BRT) lanes
- Private shuttle bus stops
- Livery and rideshare pick up and drop off
- Protected bike lanes
- Parklets
- Bike corral parking
- Electric vehicle (EV) charging stations
- Docked bikeshare stations / shared micromobility zones
- Loading zones / temporary parking
- Personal car parking

Figure 2. Protected Bike Lanes, Parklets, and Bus Stop

Photo of Telegraph Avenue with protected bike lanes, parklets, and bus stop in Oakland, CA (2021)

Recognizing the physical space of color curbs and the opportunities for streamlining day-to-day operations, many downtowns have a detailed and deep list of codes and colors for curb zones, including loading zones, conditional parking regions, handicap zones, and no-stopping zones. Developing an understanding of where these zones are located (and how they function) will be an important part of understanding traffic flows and restrictions and will allow for more informed siting of potential ZE delivery zones and other curb space policies, improving existing traffic and serving local businesses in an efficient and convenient manner.

The most common way to regulate curb space usage is through painted curbs. Curb space use, when determined by a painted curb, tends to be fixed and allows for little variability. **Table 1** below summarizes the common curb colors and what each color indicates. While there is a general consistency for what each color represents, slight variations in parking restrictions and painted curb space uses exist.

Table 1. Typology of Color Curbs

Resources	White / Unpainted	Blue	Green	Yellow	Red
SFMTA Curb Management Report	Passenger Loading	Accessible Parking	Short-term parking	Commercial Loading (Freight)	No Parking
Safe Routes Info	No parking restrictions unless indicated by a sign	Parking for the disabled with a disability placard or license plate	Limited duration parking	Drop-off/pick-up only	No parking, may also indicate fire lane
The Press-Enterprise	White: pick-up/drop-off	Unlimited parking for a disabled person with a disability placard or plate	Limited-time parking	Commercial loading; if non-commercial loading/ unloading, must remain with vehicle	No stopping, standing, parking
Hoboken, NJ	Restricted via meter or permit regulations	ADA compliance	Rideshare/taxi/ personal vehicle pick-up/drop-off	Special parking only – loading, extended parking	No parking, Emergency/ municipal response vehicles expected

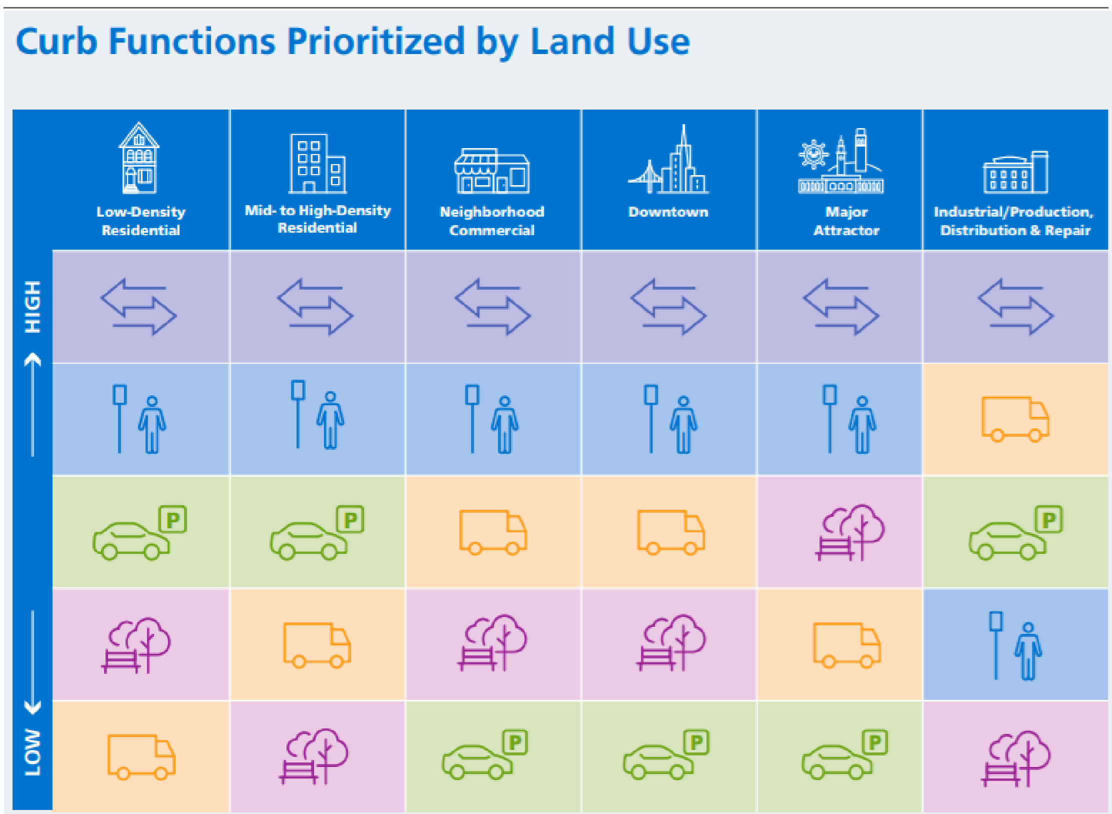
Public Uses of Curb Space

Municipalities convey several messages through curb space management. Some are non-verbal, such as curb colors, whereas others include signage—sometimes creating more confusion than clarification—about utilizing the curb. Multiple jurisdictions and agencies regulate streets and curbs. Examples include but are not limited to: Department of Transportation (DOT), Department of Public Works (DPW). To balance the demands of curbs for people and goods movement, municipal regulators must coordinate closely with fellow agencies and departments.

The competing demands for curb space may apply differently depending upon density and zoning, throughput, truck routes, and street design. The San Francisco Municipal Transportation Agency (SFMTA) produced a curb space management plan and characterizes curb space prioritization in the following diagrams (**Figures 3 and 4**):

Figure 3. Curb Functions Typology (SFMTA, 2020)

Figure 4. Curb Space & Land Use Considerations (SFMTA, 2020)



In the San Francisco materials above, through-movement is always the highest priority, but the relative value of goods access has the highest differentiation among all curb uses. In low-density residential areas, curb space for goods access is assigned the lowest value, but in industrial sectors, goods access is at the top of the list. This demonstrates how competition for curb space can vary greatly and is factored differently depending upon a neighborhood's characteristics. With the neighborhood land use typologies as a guiding principle, it presents the opportunity for transforming street space for a variety of uses that compliment, not compete.

Transit Bus Stops and Shelters

Buses are an essential component of transit networks, connecting passengers to rail and key destinations. For the system to run efficiently, roadways and dedicated Bus Rapid Transit (BRT) lanes (see **Figure 5**) need to remain clear of all non-bus vehicles. Bus stops are typically denoted by a no-standing zone, starting from a bus stop sign and ending at the next parking sign. With the implementation of traffic calming designs, such as curb extensions and bulb-outs, bus stops can also be located on floating islands.

In some jurisdictions, bikes are also permitted to use BRT lanes. Lanes typically must be 13 feet or wider to ensure space for a bus and cyclists to safely pass one another. Bus lanes can be restricted based on traffic conditions or peak hours, or they can always be in effect.

Figure 5. Bus Stops and Bus Rapid Transit Lanes Occupy Curb Space

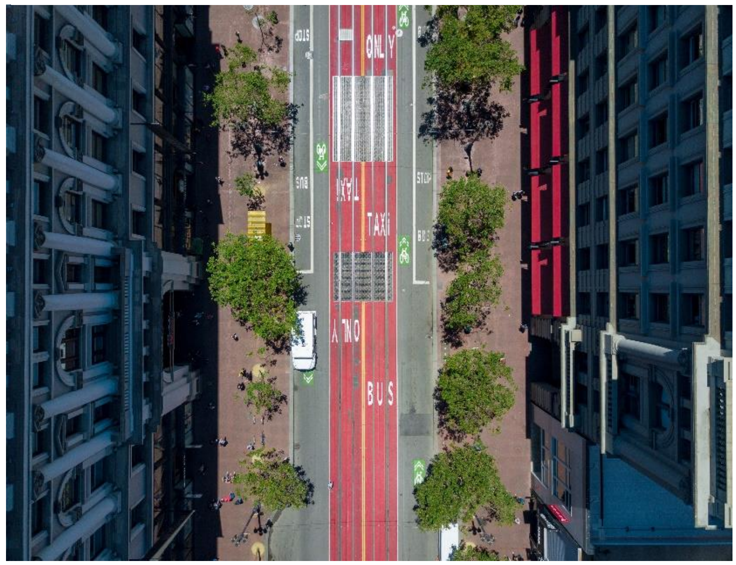


Photo credit: Szarapka, S. (2017)

Bike Infrastructure

The main types of bike infrastructure, in order of level of physical separation, are protected bike lanes (PBLs), bike lanes, and sharrows (painted markings on roadways shared with motor vehicles). PBLs are physically separated either by flex posts, concrete barriers, or greenery. Typically placed alongside the curb, PBLs restrict vehicle curb use, which builds out a safer, calmer street network. The lanes are typically the width of the former parking lane. To accommodate this new infrastructure, parking is either reduced or moved to serve as a buffer.

Bike lanes are part of a comprehensive Complete Streets infrastructure network, which focuses on designing roadways for a diverse array of transportation modes (buses, biking, and walking) for people of all ages and abilities (USDOT, 2015). A Complete Streets approach focuses on safety and balancing the competing needs for transportation and curb space requirements from safety and usability perspectives. Complete Streets intends to support complimentary policies, such as Vision Zero, which is a policy focused on eliminating traffic-related deaths, mitigating congestion, prioritizing transit, and ensuring the successful operations of competing daily street space uses.

Parking Payment Kiosks / Meters: The Economics of Curb Space

Comprehensive planning for metered parking, loading zones, and placement of payment kiosks is a key use of curb space in cities throughout the United States and abroad. For example, metered parking is common in Manhattan's Central Business District (CBD), but on most residential streets, parking is free. Most areas of NYC use municipal Smart Meters, which allow for less infrastructure and instead use a computerized system that can be changed. Digital parking payment services are available to compliment the physical infrastructure such as color curbs, which denote the specific zones based on vehicle types that can park or dwell.

Calculating the Economic Cost of Parking

Curb space, like other types of space in a city, has an economic value based off its surroundings. The economic cost of parking can be defined as the opportunity cost of not using the curb space, subtracted from the gain of curb space users.

Economic Curb Value = Gain from Usage – Opportunity Cost

In a dense commercial zone with high pedestrian traffic, opening the curb space to pedestrians can increase pedestrian throughput and comfort, and thus lead to a higher amount of shopping (economic output). In this respect, the economic value of the curb is represented by the gain resulting from using the curb space for a specific purpose, minus the opportunity cost. For a metered parking space in a commercial area, the gain could be represented by the average spending of a driver on goods in that area, and the parking revenue received from the driver's parking decisions.

Although costs vary city by city and by location within each city, the following illustration can be used to get a general idea of the opportunity costs of parking. The dimensions of the average parking space are 9 feet by 24 feet, or around 250 square feet. Rather than serving as a parking space for one car, this space could be used to comfortably place about six bike racks, allowing for six potential customers for neighboring businesses. This increases the average productivity (e.g., revenue generation) of a parking spot by more than 600 percent (Lee, 2008). Alternatively, one parking space could provide enough space to seat 12 people at a restaurant, or it could be a valuable neighborhood resting spot with a tree and a bench. This curb space could also be used as a wide bicycle lane, suitable for side-by-side riding and passing. When the space is used for parking, these other options represent opportunity costs. A 10-foot stretch of curb next to a popular restaurant could generate thousands of dollars in sales tax revenue and economic gain, but instead may be used as static parking.

A section of curb in a residential area could be used as a parklet or for mobility services such as bike and scooter share, which may increase property values with residents viewing the neighborhood as more accessible. A 40-foot stretch of curb could be reallocated to a local logistics company, expediting delivery, and saving on labor costs. In many areas, particularly more suburban ones with less access to transit, the curb space equation would favor parking as providing storage for cars. To address the car-centric consideration, framing curb space as a value proposition as part of revitalization efforts and smoother operations for reliable goods is beneficial.

The Victoria Transport Policy Institute further illustrates an opportunity cost in a non-monetary way in the following example (Victoria Transport Policy Institute, 2020):

> *For example, about 30,000 people commute to downtown Victoria [BC, Canada] each day, about 20,000 by automobile and 3,000 by bicycle. If converting one-mile of on-street parking to bicycle lanes reduces parking supply by 100 spaces, but by improving cycling conditions would shift an additional 1% of automobile commuters (i.e., 200 commuters) to cycling, the result would be a net increase of 100 spaces in downtown parking supply.*

Policies, such as on-demand pricing, can be implemented at certain times of day or days of the week through physical signage, parking meters, or via a digital application on a cell phone. During the COVID-19 pandemic, many spaces adjacent to the curb were converted into areas for outdoor dining. This is typically done by reallocating previously dedicated parking spaces through permitting to serve as another type of use, which acts as another form of economic generation and cultural capital.

However, there are many variables associated with quantifying the impacts of curb space reallocation planning efforts. In many cities, the main economic use case of curb space is fare retention at parking meters and at municipal-owned parking lots and structures. For motor vehicle parking, construction costs vary, with estimates ranging between $5,000 to $10,000 for a surface parking spot and a basic parking structure costing approximately $15,000 to $25,000 for each spot, with underground parking costing even more. Soft costs, including planning, design, and permitting, can increase costs by another 30-40%, and annual maintenance costs per space can range from $200 to $800 (Victoria Transport Policy Institute, 2020).

In addition to the costs associated with personal vehicle storage, the opportunity costs are the loss of benefits that would have been gained by using the space for another purpose. For example, if the space were used as an EV charging spot for carshare or used to create a bike lane, this could reduce the number of trips driven in personally owned vehicles, with a reduction in GHG emissions and more multi-modal trips connecting people with public transit. Furthermore, if parking spots were instead a restaurant, thousands of dollars in tax revenue and business revenue can be generated in the same timeframe. Some municipalities such as Berkeley, California, calculate the expected revenue and build it into the permitting structure for parking spot relocation. Analyzing the actual cost of parking beyond the meter can begin to unlock the immense potential of the curb, both in terms of revenue generation and the economics for small businesses.

Another important and related concept is curb productivity. Curb productivity can also be defined as activity divided by time multiplied by space.

*Curb Productivity = Activity/(Time*Space)*

The impact of bicycle or pedestrian infrastructure requires the reclassification of curb space from parking to other uses to be defined. By subtracting the impact, if any, of removing travel lanes or parking spaces, and adding the increase in curb productivity brought on by increased bicycle volumes/throughput, public stakeholders and policy makers can begin to quantify what is missing with effective curb space management.

In New York City (NYC), reallocating just 5% of parking spaces in the core downtown area (2,200 parking spaces) would reallocate over 10 curb miles of space, or approximately 475,200 square feet. This could enable over 1,000 truck loading spots, 10,000 additional bike parking spots, or create socially distanced outdoor seating for over 26,400 people. These examples illustrate why opportunity costs and alternative uses of curb space are so important to consider.

Goods Delivery

Electric delivery trucks in city areas are commonly dispatched from a central location (logistics hub) and go door-to-door dropping off packages. EVs that use regen braking benefit from start and stop urban traffic, long highway stretches can limit range. Trucks may have to spend valuable time deadheading back to the logistics hub, and while residential deliveries add value to the curb, charging electric trucks in loading zone would prevent other trucks from utilizing it. A solution to this problem could involve fast/smart EV charging at hubs, leading to reduced overhead costs from storing additional trucks. Moreover, low-value curb areas could be repurposed for Direct Current Fast Charging (DCFC) charging mid-route, situated in areas with a low demand for curb space (e.g., empty lots, medians, gas stations). In NYC specifically, marked, and charging stations could occupy a few spaces in Midtown Manhattan and enable vehicles to charge quickly along delivery routes. With the addition or encouragement of batteries or alternative power sources, logistics hubs could be more resilient and lead to less variable demand, which would help power companies distribute electricity without the risk of grid overload (Mai, 2018).

Shared Micromobility

Micromobility encompasses lightweight shared vehicles such as bikes and scooters. Part of the last mile connection to transit and used for short trips between 1-3 miles, micromobility has become part of the transportation ecosystem in cities throughout the United States. To keep up with the demand for dockless bikes and scooters, municipalities allocate space for micromobility parking zones adjacent to curb space, as seen in **Figure 6**.

Figure 6. Dedicated Shared Micromobility Parking Zone

Photo of dedicated shared micromobility parking zone in Santa Monica, CA (2021)

Bikeshare is a foundational use case of curb space in some cities, including Boston, Chicago, Los Angeles, Oakland, San Francisco, Washington D.C., and Chicago. Docked bikeshare, as seen in **Figure 7**, has physical stations that occupy curb space. The docks serve as a place for users to both remove and place bikes for end-to-end trips.

Figure 7. Citi Bike Station

Photo credit: Greenberg, J./Universal Images Group via Getty Images (n.d.)

EV Charging Infrastructure

Electric vehicle supply equipment (EVSE) is another pre-existing curb use that is expected to increase in the coming years. EVSE station deployments are typically part of a larger make-ready program and require alignment between public and private sectors for siting and deployment. When deployed along the curb, EVSE require space for the dispenser and space for a cable to run between the dispenser and the EVs. There must be adequate space behind the dispenser for pedestrian traffic without causing a trip hazard. Additionally, grid capacity considerations and peak usage scenarios, such as heat waves or wintry weather conditions, must be factored in when adding electric charging stations to a utility network; Level 2 and DCFC stations can add the equivalent of hundreds of households in electrical demand, so smart charging or off-peak charging scenarios should be considered as part of a comprehensive Transportation Management Plan (TMP).

Adaptive Uses of Curb Space

During the COVID-19 global pandemic, restaurants and small businesses were struggling to survive. By repurposing curb space through the implementation of parklets and curbside pickup, many cities made dramatic changes to existing permitting associated with curb space regulations and some closed streets to motor vehicles.

Figure 8. Outdoor Dining Street Closure

Photo of road closure due to extended outdoor dining in Berkley, MI (2021)

To support the curb space needs of restaurants, the city of Ann Arbor, Michigan, waived permit fees for all downtown businesses, allowing restaurants to utilize sidewalk space for outdoor seating. The city also repurposed on-street parking for use as outdoor dining for 40 restaurants. Some cities, such as Berkley, Michigan, (see **Figure 8**) closed sections of streets to accommodate extended outdoor dining. The impacts of efforts demonstrate the economic power of repurposing parking to different uses.

While restaurants were looking for creative ways to seat patrons, they also adjusted business models to accommodate for curbside pickup. At times, restaurants and stores were open for curbside pickup only and did not allow in-restaurant ordering/pickup or in-store shopping. Due to in-person capacity restrictions, businesses adapted to the changing landscape of consumer demand and transformed conventional retail stores into quasi-warehouses to fulfill orders. Curbside pickup also resulted in many motorists requiring short-term curb space to pick up orders.

Many cities converted curbside parking spaces to meet this demand. Looking again at Ann Arbor, the city converted on-street parking into 15-minute pick-up and drop-off (PUDO) zones (Hanzlik, 2021). The City of Los Angeles implemented a curbside pickup program to help restaurants handle the COVID-19 crisis. Restaurant owners could obtain signage free-of-charge (see **Figure 9**) through the Los Angeles Department of Transportation (LADOT) and converted single parking spaces to short-term loading zones, for up to ten minutes of parking to allow customers to pick up goods (LADOT, 2021).

Due to the limited number of people allowed inside at once, grocery and similar businesses had long lines of customers waiting to enter. San Francisco is one city that officially adopted a "Shared Spaces" program that accommodated needs for long lines outside of stores, PUDO spaces, and outdoor dining space during the pandemic (Hanzlik, 2021). In more sprawling cities and towns, parking lots adjacent to big box stores and malls were retrofitted to accommodate shipping containers in parking lots for strategic and faster fulfillment and distribution.

Figure 9. Curbside Pickup

Photo of curbside pickup signage in Los Angeles, CA (2021)

CURB SPACE MANAGEMENT FOR DELIVERIES

Goods movement and demand for online commerce and delivery increased exponentially starting in March 2020 during the COVID-19 pandemic and beyond. With the shift in consumer behavior towards online ordering, planning for curb space demand peaks and utilization is an important component of comprehensive operations. With advancing technologies in last mile delivery and goods movement such as time of day utilization, prediction modeling and data analysis can help to solve challenges that members of the public, municipalities, and delivery companies all face. By future-proofing ordinances and policies to have adaptable uses to public right-of-way, it improves the safety and usability of streets and sidewalks for all.

The pandemic accelerated trends associated with online shopping and daily essential goods delivery. In July 2020, online shopping increased by 55 percent compared to July of the previous year, and 30 percent of survey respondents reported shopping online for products that, prior to COVID-19, they would purchase in-store (Gothivarekar, 2020). With the shift in purchasing patterns, there has been a resulting shift in curb space needs. More short-term parking is needed for delivery vehicles to utilize, and less curb space is needed for longer parking times, such as for people going shopping.

Kicking Inefficiencies to the Curb

Improved efficiencies in goods delivery through effective curb space management policies and smaller EVs to make deliveries mitigates congestion and increases the number of deliveries per hour while reducing GHG emissions. Class

4 trucks are often used for residential deliveries; while this enables more deliveries to be done with one truck, the introduction of small-scale delivery vehicles, such as cargo electric bikes (cargo e-bikes) and automated vehicles (AVs) will facilitate efficient deliveries without high-emission vehicles. Right-sizing fleets (such as using cargo e-bikes for smaller packages in areas with density and safe infrastructure) and converting larger internal combustion engine (ICE) vehicles to smaller EVs is a test in public/private partnerships.

When municipalities incorporate the learnings of the COVID-19 pandemic in curb space policy development and private sector delivery and logistics companies accelerate testing new types of fleets, the two innovations complement each other and accelerate adoption rates. Bringing together the advancement of technology from the private sector with policy development from the public sector ensures a system of checks and balances for product development and supporting policies as part of program launches and daily operations.

Pedaling Progress in New York City

Recent legislation in NYC has legalized a long-standing courier industry that uses classic pedal bikes and cargo e-bikes to make deliveries. Now that Class 1 e-bikes that go up to 25 mph are legal in NYC, delivery providers can utilize bikes with more security. The city recently legalized 55-inch-wide cargo bikes, which enables companies, such as FedEx, DHL, Amazon, and UPS, to provide delivery services through innovative and high-capacity cargo bikes (see **Figure 10**).

Figure 10. FedEx Cargo E-Bike

Photo credit: Curbside Cycles (2020)

The e-bike delivery future of NYC is a flagship example of transitioning towards lightweight vehicles for last mile delivery. By incorporating policies from cities such as Oslo, Norway; Oakland, California; and San Francisco, California, the public sector will become responsive to the rapid technological changes happening in the private sector. Logistics innovations, such as last mile microhubs, digital tools to manage physical curb space, robotics, and lightweight EVs (e.g., bikes), will not only increase efficiencies in deliveries but will play a vital role in reducing noise pollution, GHG emissions, and vehicle miles traveled (VMT).

Considering the frequency and type of deliveries based on factors such as time of day, weight, and frequency, there are opportunities for developing policies to support long-term operational efficiencies by leveraging both physical and digital infrastructure enhancements, such as signage, physical barriers on the street, and app-based technologies (which are currently being tested in some markets such as Miami) for managing curb space reservations for loading and unloading.

Domestic Case Studies

Innovations in curb management and improved freight systems are happening in cities across the United States. Each of the examples is unique to a particular urban design and city planners' goals, but these early efforts offer valuable lessons for incorporating new freight policies and technologies into cityscapes to meet shifting consumer needs.

Boston Downtown Crossing Pedestrian Zone

Figure 11. Pedestrian Zone Signage in Downtown Crossing

Photo credit: Downtown Boston BID (2014)

Located in Boston's Downtown core, with proximity to rail stations, retail, and offices, the pedestrianization of Downtown Crossing is due in part to the economic power of creating safe, shared biking and walking areas. In the Downtown Crossing zone (see **Figure 11**), pedestrians are prioritized while all non-permitted vehicles must detour around the area during time-of-day restrictions. Delivery trucks are prohibited from loading and unloading during peak pedestrian times. Authorized delivery vehicles, taxis, and Massachusetts Bay Transportation Authority (MBTA) buses can enter the zone to perform pick-ups and drop offs. Trucks must have a commercial plate or a permit and can load for up to 30 minutes.

Future studies in the Boston Downtown crossing delivery zone are considering an expansion of the existing traffic free zone or closing off additional streets to motor vehicles for pedestrian and bicyclist movement. As the Downtown Crossing area undergoes redevelopment, greater attention towards shared streets and safety are a top consideration for residents, planners, and delivery providers.

New York Curbside Loading Pilot

NYC DOT Loading Zone pilots in residential neighborhoods like Cobble Hill, Upper West Side, and Chelsea are great for residential deliveries, which typically do not have dedicated space as in more industrial, office, and commerce-based areas. These pilots ensure that deliveries can be made during normal hours (7am-7pm), while also enabling cars to park overnight (Cuba, 2019). By modifying curb space regulations based on the time of day and needs of the businesses and residents, these pilots minimize opportunity costs. This is a reasonable compromise solution, as curb space becomes inherently less valuable in the middle of the night based on demand (NYC DOT, 2021).

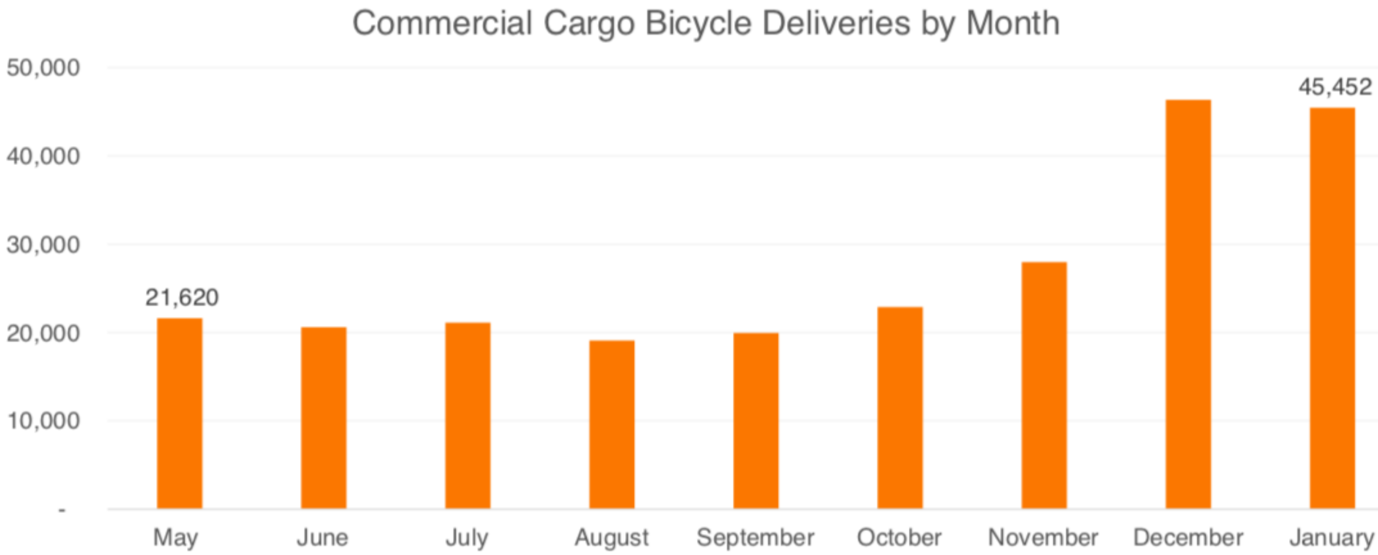
Los Angeles Zero-Emission Loading Zone Pilot

The City of Los Angeles, working with regional and national freight operators and clean transportation organizations, identified zero-emission loading zones as a policy opportunity that could be quickly and directly implemented. In June 2021, the City Council authorized an ordinance that will establish five initial zero-emission loading zones within the city as part of an effort to encourage early-market zero-emission freight adoption by fleets operating in Los Angeles. The ordinance allows city planners to establish loading zones that are only accessible to zero-emission vehicles, creating an incentive to freight operators that will be able to quickly deliver goods at reliable locations without incurring parking fines. The locations will be established in areas that are high-density, commercial areas, and are disproportionately impacted by air pollution burdens (NBC, 2021).

New York Commercial Cargo Bicycle Pilot

Primarily based in Manhattan, “the Commercial Cargo Bicycle Pilot launched on December 4, 2019, with three participants (UPS, DHL, Amazon) and 100 bikes. As of January 2021, there are 6 participants and over 350 bikes in the pilot” (NYC DOT, 2021). Based on the evaluation report, some metrics measuring the impact of transitioning vehicle trips. Metrics include measuring CO2 reductions, conversion from ICE delivery vans and miles traveled. The regulatory and policy landscape focused on cargo e-bikes cultivates the environment for testing out a preliminary pilot and carrying it forward as an expanded initiative. The preliminary data in **Figure 12** below quantifies the number of packages delivered by cargo bikes. The colder months were also the same time that the delivery zone expanded. It is interesting to note that weather did not seem to be a deterrent in using the cargo bikes for last-mile commercial deliveries, proof that cargo bikes can be used year-round and not solely during warm weather months.

Figure 12. Number of Commercial Cargo Bike Deliveries by Month Throughout Duration of Pilot (NYC DOT, 2021)



Santa Monica Zero Emission Delivery Zone Findings

The City of Santa Monica was chosen in 2020 as the site of an optional ZE freight delivery zone. Managed by the Los Angeles Cleantech Incubator, the collaboration brings together neighborhood and business groups with city managers and targeted private technologies to create a test area in one square mile of downtown Santa Monica. The goal of the project is to introduce cleaner, sustainable delivery modes to the commercial Main Street corridor. In doing so, the project plans to explore several best practices, such as right-sizing of vehicle fleets with optimal technical solutions, how to make use of land and zoning plans, and how local businesses can benefit from ZE delivery.

The effort is only beginning to reach maturity, but the ZE zone is noteworthy for its collaborative approach and engagement with key stakeholders:

- Business-oriented organizations focused on Santa Monica have organized and coordinated with residents to highlight the benefits of ZE technologies and to acclimate residents to the new and often surprising technologies, such as autonomous delivery robots.
- Resident committees and associations have been valuable partners. Getting these groups involved early and maintaining engagement has generated good will, helped negotiate most concerns, and established the most effective geographies for the zone and its ZE loading zones.
- Additional to businesses and residents, the number of agencies that the City of Santa Monica has involved has been expansive, including parking, parks, city mobility, public works, police and fire, and IT security.

Identifying which transportation modes are most effective has been an ongoing research goal, with multiple companies' technologies tested to date or planned:

- The City of Santa Monica has recognized the value of smaller, more nimble technologies that can readily make use of existing travel and curb corridors. Electrified cargo bikes have consequently been a practical early technology in this pilot.

- REEF, the largest parking operator across North America, is using its nearby facilities as distributed freight hubs where cargo can be unloaded onto these electrified cargo bikes for last-mile delivery.
- Nissan has dedicated several electric cargo vans and plans to deploy some larger, class 6 trucks into the zone.

Day-to-day operations associated with curb space management has been delegated to a private company, Automotus, which has installed cameras on traffic poles around Santa Monica. The tech company's cameras monitor traffic and delivery patterns to identify 20 or more sites that are optimally suited for ZE curb access. Automotus' technology allows project managers to track operational characteristics at curbs, including dwell time, double or triple parking, and which vehicles access the curbs.

The project has shown great promise to test collaborative and new technological approaches, but current experiences have also raised a few pertinent questions or issues that managers hope to resolve:

- Automotus can track curbside uses, but it cannot accurately track the full vehicle system in Santa Monica; fleets have also been reticent to share their operational data. This information would be useful to manage traffic, predict and manage curb uses, and schedule access to the ZE loading zones.
- Curb access is being created for ZE operations, but enjoining fleets to participate is an uncertain process. The City of Santa Monica is considering strategies to promote ZE access to fleet operators, such as preferential access or the value of avoiding parking tickets that accrue when double-parked.
- The ZE zone is not generating any revenue, so to support private partnerships or to offset reduced revenue from parking tickets, city managers are considering a ZE loading zone access fee that fleets would pay to participate. The fee would be set at a level less expensive than typical parking tickets, so available revenue would be split by the city and the fleets, who would still have preferential access to loading zones.
- The ZE zone is voluntary, and the city currently does not have the authority to levy fines against non-ZE vehicles that use the ZE loading zones. Signage and educational campaigns have been considered as methods of preventing non-compliant vehicle use, but these strategies have not yet been tested.

SECTION II

II. PLANNING FOR FUTURE POLICY DEVELOPMENT

As part of the preliminary research into the feasibility of designing and implementing curb space management policies, transitioning to lightweight EVs for last mile deliveries, incorporating microhubs, and developing ZE delivery zones, the CALSTART team recommends municipalities take the following variables into consideration:

a. **Zoning:** Serving as a baseline in determining the land use patterns of residents and businesses located within the proposed project area, this data provides a visual representation of various use cases to strengthen the implementation for certain policies and/or programs that focus on ZE delivery and curb space management.

b. **Equity Considerations:** With the development and implementation of curb space management policies that may limit vehicular access to certain blocks of the city, working with community stakeholders and community-based organizations will be important to ensure that measures are developed with buy-in and feedback from residents and business owners. Taking a data-driven approach to embedding equity at the onset of policy development will facilitate successful operationalization of the measure(s).

c. **Landscape Analysis of Pre-existing and Complementary Policies:** This should involve and be completed across various departments such as transportation, parking, enforcement, economic development, and legal.

d. **Bike Infrastructure:** Mapping routes of dedicated bike infrastructure is useful as a foundation for determining the best routes for cargo-bike deliveries and bike rack parking.

e. **Business Improvement Districts (BIDS):** Depending on the municipality, datasets of BIDs can be used as overlay to identify local small businesses to partner with and to conduct community engagement with to ensure buy-in and support from local stakeholders.

f. **Transit Network:** Incorporating data of all transportation modes (e.g., bus, rail) and bike infrastructure will provide a focus area to pilot curb space management strategies, such as car-free zones, flexible loading zones, and time of day restrictions.

g. **Truck Routes:** Pulling data on vehicle operations will support the rightsizing of vehicles and fleets, establish charging needs, and improve the efficiency of driving cycles.

PUBLIC POLICY CONSIDERATIONS

Policy is one of the most critical drivers of effective curb space management. Regulations create better adoption conditions, and thus greater demand for right-sized EVs and human-powered vehicles for last mile delivery. Various levels of government play a role in accelerating demand for and reducing barriers to cleaner vehicles operating in cities. These policies in **Figure 13** demonstrate the nesting of the delivery landscape. Thus, local-level policies that focus on the operations of effective curb space management are an essential component of the broader scoped municipal policies focusing on broader safety and infrastructure improvements.

Municipal Policies

Within the United States, California cities, such as Los Angeles, Santa Monica, San Francisco, and Oakland, are accelerating efforts to effectively manage curbs as part of the transition from ICE vehicles to EVs as well as focus on improving air quality and decreasing noise pollution. European nations and cities have begun to set targets for ZE delivery zones and, in some locations, to implement pilot projects or larger-scale programs.

Figure 13. Policy Frameworks

Developing or modifying new policy requires coordination between transportation, public space, land use, and legal departments as well as coordinating with the zoning boards. Each municipality operates differently, but it is a good practice to bring in stakeholders at the onset of policy development.

- London's **Ultra Low Emission Zone** requires payment for vehicles that do not meet emissions standards to drive into the boundaries of the central city. As emissions standards for commercial vehicles increase, ZE freight operators will save on paying to access central London.
- Oslo has removed parking spaces in its downtown business district, only leaving space for handicapped parking access and loading zones. This action has created opportunities for ZE freight vehicles including cargo vans and electric delivery bikes.
- Munich has allowed ZE freight operators to complete deliveries during off-peak evening hours that would normally be restricted due to noise concerns. The vehicle operators report that their routes are being run with up to 30 percent greater efficiency due to lower traffic volumes (Manthey, 2021).

Based on these current and ongoing examples, below are recommendations for public/private partnerships in effectively managing curb space:

- Engage with local community groups and adjacent business owners at the onset of policy development, including, but not limited to the implementation of ZE delivery zones.
- Focus on building consensus across regions focused on ZE technologies that connect with curb space management best practices.
- Collaborate with city planners and agencies to identify how policies can prioritize ZE access, such as off-peak

delivery access or reduced residential parking.

Taxis, Liveries, Ridesharing / Transportation Network Companies (TNCs) Landscape

A common use for curb space is taxi pick-ups and drop-offs. NYC is famous for its yellow and green taxis and black livery rides, but transportation network companies, such as Lyft and Uber, continue to rise in popularity. The number of licensed traditional livery vehicles has remained constant, but they have driven fewer miles and trips as TNCs (Transportation Network Companies) have absorbed traditional livery market share. However, TNC growth has far exceeded the reduction in traditional livery trips, leading to a rapid increase in the number of vehicles that add to traffic congestion and clog curbs. To help address the issue of unregulated and unchecked TNC growth, the City of New York capped the number of registered TNC vehicles in 2018 and extended the cap in 2019. These trends are demonstrated in **Figures 14 and 15.**

Figure 14. Unique Vehicles per Month, NYC (Schneider, 2021)

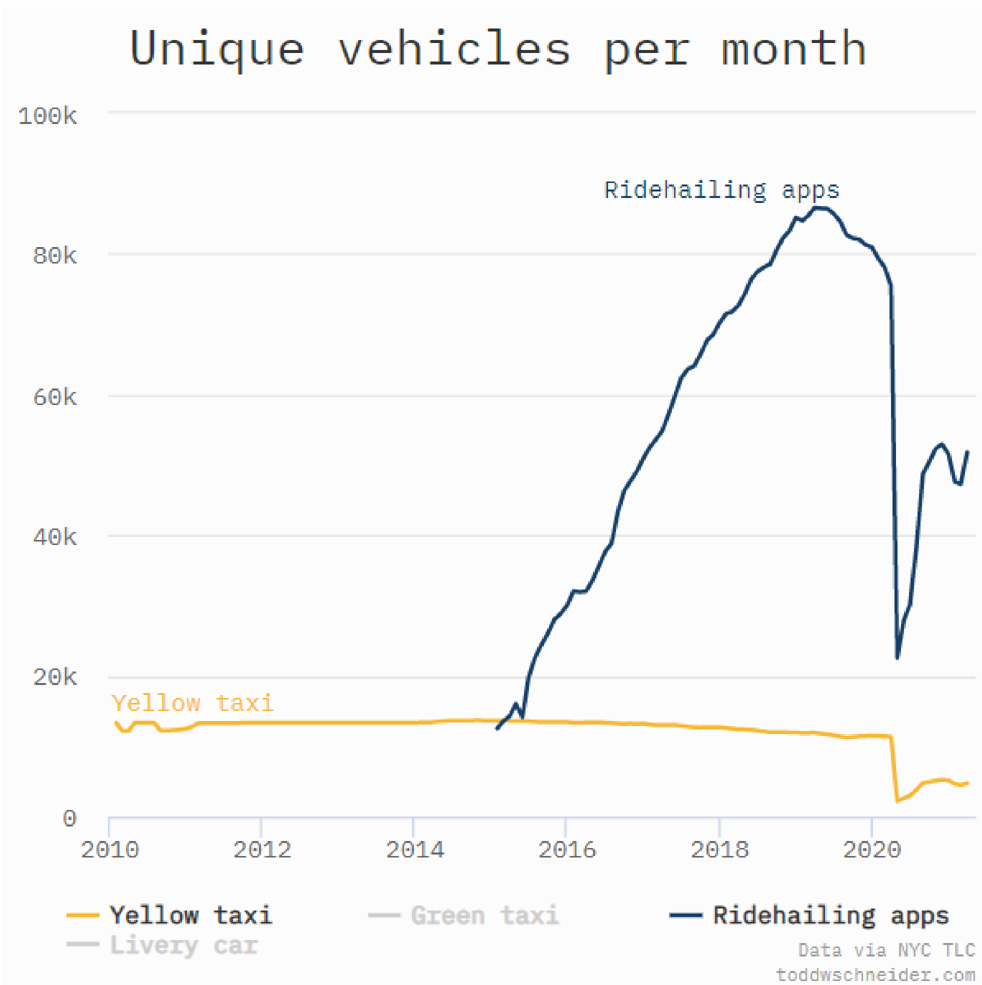
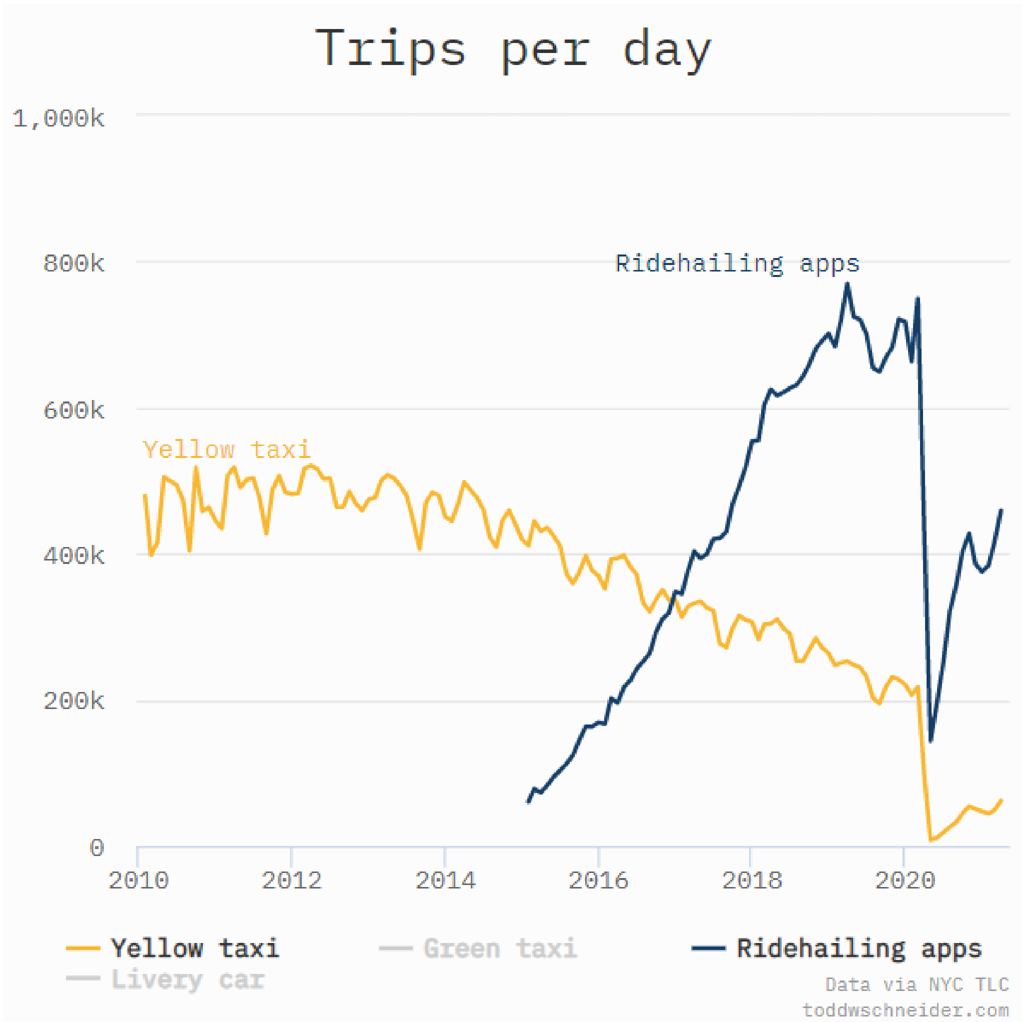


Figure 15. Unique Ridesharing Trips per Month, NYC (Schneider, 2021)



Traditional taxi and livery vehicles have typically operated along city streets, stopping as needed along curbsides, but also in street locations that may impede vehicle or bicycle traffic. In particularly high-use areas, such as transit hubs, planners have mitigated the effects of taxi traffic by reserving curb space or service road access for taxi use. These taxi lanes can be found in urban locations, such as NYC's Grand Central Station (curb access) and Washington DC's Union Station (access roads).

Managing TNC and taxi operations is most effective at transit hubs, eating-and-drinking hot spots, and tourist destinations. TNCs reduce the need for drivers to find parking and to pay for the spaces at these locations, providing door-to-door service. However, the impact on private vehicle ownership and associated parking needs is less notable outside of these specific applications (Wadud, 2020; Ward, 2021). TNCs tend to displace transit use, but not vehicle ownership, which will continue to impede curb access when lined with idle passenger vehicles. In a study conducted over several years across multiple cities, VMT were found to increase as TNCs proliferate, but private vehicle ownership declines approximately one percent.

GOING FORWARD: CITIES OF THE FUTURE

Recent policy innovations in cities throughout the United States have kickstarted the transformation of curb space, with goals to improve air quality and reduce noise pollution by weighing the competing benefits of the curb. As discussed previously in detail under Santa Monica Zero Emission Delivery Zone Findings, Santa Monica's ZE delivery zone is within a one-square-mile area in the core of the city; the zone works to reduce the pollution and congestion caused medium-duty trucks commonly used for urban deliveries and can also be used as a testbed for robotic vehicles, multimodal micromobility fleets, and outdoor dining. In Los Angeles, the Department of Transportation solicited an RFP (Request for proposals) for a ZE delivery zone. This project would establish a one to six square mile area in a high-density neighborhood and would be a voluntary program targeting larger parcel delivery companies. The desired goal is to improve air quality and noise pollution, but side effects would include more e-cargo bikes or designated EV loading zones within the study region (LACI, 2020).

In certain international cities, such as Amsterdam and Ghent in The Netherlands, zones where most ecommerce deliveries are made by e-bikes already exist. The public mail service in Amsterdam will switch to an entirely e-cargo bike fleet by 2025 and has recently expanded their e-bike delivery zone beyond the dense urban core. In Dutch cities, the idea of e-cargo bicycles has spread to the general population; startup companies are offering cargo bike rental services (Srivastava, 2019).

The launch of cargo bike sharing services, along with major companies using e-cargo bike delivery, makes it possible for the average person in Amsterdam to use a bicycle for all use cases, including light goods transport. This significantly reduces the space needed to host trucks on city streets and serves to "open the curb." Because bicycles can be parked in a more spatially efficient manner than cars and trucks, the curb can be opened and used in a people-friendly fashion.

There are efforts being made to shift towards e-bike and ZE vehicle delivery through meeting emissions targets. In Edinburgh, Scotland, low emissions zones in the urban core are being studied; in these low emissions zones, polluting trucks and other vehicles would be banned, which would encourage delivery companies to switch to e-bike or other forms of local delivery. In London, low emissions incentives are already partially in place thanks to congestion pricing systems.

Oslo Strategizes to Develop Newer, Cleaner City

The City of Oslo is dedicated to improving the experience of city life and maintaining livability for generations to come. The city is developing GHG emissions reductions strategies in ways that will return the city to pedestrians, such as shifting away from vehicle use and encouraging bicycle travel. In 2017, to reach **its transformative goals**, the city set a target of achieving zero emissions by 2030 and developed a carbon budget to allocate carbon expenditures. Developed with local stakeholders and overseen by Oslo's Department of Finance, the carbon budget creates a transparent allocation for each of the city's departments and enables the public to track progress. Given the wide-ranging nature of reducing city emissions and a timeline of zero emissions within 13 years, achieving Oslo's climate and livability goals required a suite of innovative and assertive policies and actions.

Many of Oslo's initiatives focus on reducing vehicular air quality pollutants and GHG emissions by reducing vehicle access and incentivizing ZE vehicle adoption for personal and commercial vehicle use. The city has added over 1,000 charge points for EVs, created exemptions on toll roads, and allowed EVs to use restricted-access vehicle lanes. Most notably, two policies combine to make driving zero-emission commercial vehicles (ZECVs), or shifting modes away from driving entirely, more attractive in Oslo:

- **A congestion tax** based on the time of day a vehicle enters Oslo reduces severe traffic, but cars and trucks propelled by electricity or hydrogen are exempt.
- The city center is **removing parking spaces** entirely, except for spaces for people with restricted mobility and freight-loading zones. Because the city will be emission-free by 2030, ZECVs will be needed to deliver goods to loading zones within the city.

Oslo's congestion tax, with exemptions for ZE vehicles, encourages individuals and fleets to adopt electric- and hydrogen-powered vehicles by saving on the costs of driving in the city relative to petroleum-powered vehicles. However, the city's goals of eliminating petroleum-powered vehicles, in combination with the establishment of a vehicle exclusion zone in the city's center, establish a strong signal that ZE vehicle adoption as a matter of business will be required within a decade.

ZE vehicle adoption in Oslo has been swift, and the city's efforts to reduce GHG emissions and improve its air quality **have already been noted** by the executive director of the United Nation's Environment Program, Erik Solheim: "I am very proud of my hometown, Oslo, which is demonstrating that by reducing the number of polluting vehicles and introducing policies that encourage a cleaner future, we can improve the everyday lives of citizens as they can breathe cleaner air." **A 2018 report by Greenpeace** indicates that Oslo is the only city in its analysis with air quality emissions below the European Union limit and World Health Organization guidelines. As a result, Oslo has been named the European Union's "**Green Capital**" and its mayor has referred to the city as the "EV Capital of the World."

To reach the city's goals of zero emissions by 2030, the city and its industry partners must continue to innovate. Delivering freight into a city center exclusively through ZE technologies is a goal that has not been achieved in large, developed cities since the ICE became popular over a century ago.

One global logistics company has already taken on the opportunity to become a leader in ZE freight in Oslo by creating a freight hub outside of the city. **DB Schenker's Oslo City Hub** established a logistics center where non-compliant trucks can deliver goods that can be transferred to ZECVs, including trucks and specially designed electric cargo bikes. By creating the first ZE freight hub for deliveries in Oslo, DB Schenker may benefit from a first-mover advantage and create a new opportunity to develop ZE vehicles to meet the needs of delivering freight in Oslo and other cities with exclusion zones, low-emission vehicle zones, or congestion pricing with ZE vehicle incentives. This example reflects the mutually beneficial role that industry partners may play in achieving city and regional targets to improve air quality and reduce GHG emissions.

Implementing paradigm-shifting policies that affect how people and goods move in a capital city was not a simple or brief process. **Oslo and other cities have navigated contentious challenges and learned valuable lessons along the way**.

- **Design Zones, Exemptions, and Prices:** The central exclusion zone contains residences and businesses that rely on current transportation options. Oslo has created exemptions for persons with limited mobility to park in the city, will allow transit buses to operate in the city center, and has established freight loading zones to supply residential and commercial needs.
- **Build Public Support:** By establishing a transparent carbon budget and providing several years of lead time to implement its policies and actions, Oslo earned support from residents and allowed them time to adjust to new transportation options.
- **Designate Revenue**: Ninety percent of congestion pricing revenue is channeled directly to funding the city's public transportation system. Providing reliable transit service is critical to promoting a viable alternative to passenger vehicle use.
- **Invest in Mobility Alternatives:** In addition to increased transit access, Oslo is building 100,000 new bike lanes by 2025 and may consider innovative technologies as they approach the marketplace.
- **Consider Related Policies:** To restrict passenger vehicle use, the city is removing parking spaces from the city center. Alternative mobility options that the city provides will become more attractive than driving into the city center.

Oslo's early successes show that a coordinated municipal effort to make a city more sustainable can succeed by engaging residents regularly and transparently, and by working with industry to meet its projected goals through innovation and seizing business opportunities. By envisioning what the city should become rather than focusing solely on strategies to reduce GHG emissions, Oslo is creating an example of how to create a new and sustainable city and community.

Congestion and Emissions Pricing in London

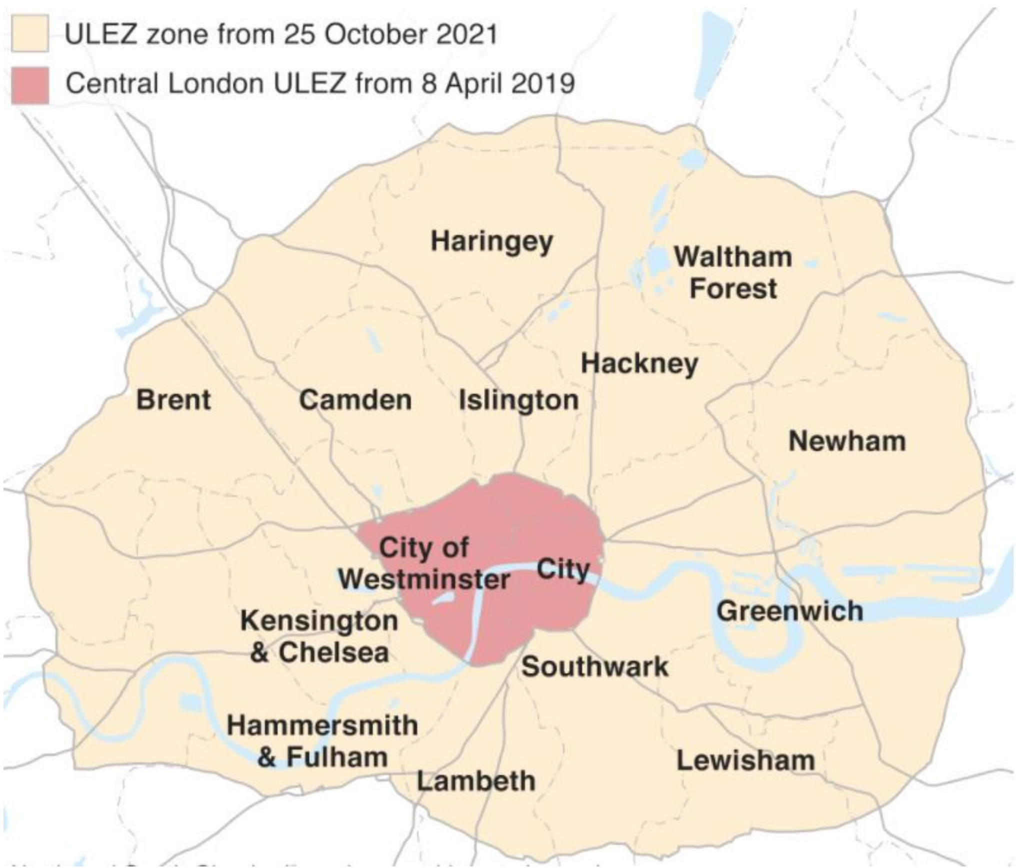
The City of London, England, has addressed its related issues of traffic congestion and vehicle emissions by implementing access fees that apply to any vehicle entering defined sections of the city. This approach puts the burden of reducing emissions and congestion on vehicle drivers by making cleaner, smaller technology options more financially attractive compared to standard freight methods. As detailed in **Table 2**, London combines three fee-based programs that may apply to urban freight deliveries: a congestion charge for central city access during business hours, a low-emission zone (LEZ) to support clean vehicles across broader London, and an ultra-low emission zone (ULEZ) set for the central city that exempts only the lowest emission vehicles from payment.

Table 2. Types of Congestion and Emission Pricing Programs in London

Program	Purpose	Location	Time	Vehicles Affected	Freight Payment
Congestion Charge	Reduce Traffic	Central London	07:00 – 22:00	All	£15 (<3.5 tons); £100 for > 3.5 tons
Low-Emission Zone (LEZ)	Reduce Emissions	Greater London	Midnight - Midnight	Light-Duty (Fee Waived for Euro VI Compliant Vehicles)	£100 - £300
Ultra-Low-Emission Zone (ULEZ)	Reduce Emissions	Central London	Midnight - Midnight	All (Fee Waived for Euro VI Compliant Vehicles)	£12.50 for <3.5 tons; £100 for > 3.5 tons

Each of these charges is considered separately (Transport for London, n.d.), though for freight vehicles the LEZ and the ULEZ requirements may be very similar (Greater London Authority, n.d.). A freight operator must enter greater London in a vehicle that complies with the LEZ emissions requirements or pay an access fee. If that vehicle continues to central London and does not comply with the ULEZ emissions requirements, the tighter regulations will require additional payment. Entering central London will also require payment of the Congestion Charge, depending upon the time of day. The ULEZ is set to expand to the borders of the North and South Circular roads that define the current LEZ on October 25, 2021. The Congestion Charge will remain solely in central London (see **Figure 16**).

Figure 16. A map of London's current ULEZ boundaries (overlapping with Congestion Charge zone) and where the ULEZ will expand to match the existing LEZ (Edwards, 2019)



The ULEZ program in London and in other U.K. cities have been planned for several years, giving freight operators time to manage their fleets to avoid costly charges. For instance, UPS has purchased and operated a hybrid-electric delivery van that can operate exclusively on electric drive when operating in emissions-restricted areas. The van uses geolocation to indicate that the van must switch from diesel-assisted drive entirely to zero-emissions drive (Etherington, 2019). In London, a centrally located business improvement district helped counsel local businesses on switching from cars and vans to bikes, supported in part by a U.K. grant that covers 20 percent of the cost of purchasing new e-cargo bikes (Edwards, 2019).

Adapting Innovative Curb Space Management Policies to the United States Market

With the popularity parklets for outdoor dining and Slow Streets programs, curb space is in high demand by restaurants and people. Transitioning towards lightweight EVs and e-bike delivery programs in American cities do not need significant modifications from their European counterparts. In high density urban areas, bikeshare can get one from A to B faster than a personal vehicle; the same rationale can be applied to an e-cargo bike and a standard delivery van. By applying data-driven approaches and clear metrics to measure success, public and private stakeholders can align on data sharing and evaluation.

Last Mile Cargo E-Bikes

Examples of shared cargo e-bikes exist in European markets and there is an opportunity to expand shared micromobility in the United States to include access to cargo e-bikes. In Berlin, residents can use shared cargo bicycles placed throughout the city to run errands. These bicycles are operated by a company called fLotte and feature a large open box on the front of the bicycle, which can hold multiple suitcases and materials. The bicycles are dockless and free to use, with over 19,000 registered users (Quednau, 2021). Similar programs could be set up in the United States, and micromobility companies in the United States are exploring alternative forms of bikeshare.

Right-Sizing Deliveries Toronto

Some pilot programs in urban cities have also turned towards e-cargo bikes to replace some truck trips, as discussed earlier about the New York Cargo Bike Pilot. In Toronto, a small-scale e-cargo-bike pilot with FedEx has proven successful (see **Figure 17**). The three pilot vehicles have a 31km/h speed limit, have internal gearing, and have 150km range and a 315-liter cargo box. The bikes are subject to winter weather conditions that can potentially be a limiting factor. Operators are required to take a safety class and the e-cargo bikes are operated in designated delivery zones which all have strong bicycle infrastructure. The e-bikes can navigate through city traffic, and early results suggest that these cargo bikes can make deliveries a lot more flexible and faster—e-bikes do not need a full parking spot.

Figure 17. FedEx Cargo E-Bike, Toronto, Ontario, Canada

Photo credit: Shissler, R. (2020)

As demonstrated by the success of Berlin's program, a cargo bicycle pilot, it is replicable in U.S. markets with complementary infrastructure and policies.

Curbs as an "Anchor" of Place

Curb usage can significantly impact the identity and the placemaking ability of neighborhoods. An active curb can act as the heart of a neighborhood. With outdoor dining and commerce occupying the space, a curb can function as the extension of the "building stoop," as described by Jane Jacobs in *The Death and Life of Great American Cities.* A curb can provide a reason for residents and tourists alike to use the street at all hours, which improves safety and strengthens the health, safety, and economic vitality of the community.

Decreasing the number of trucks and large vehicles needed in the delivery industry can free up valuable space on streets, enabling more outdoor dining (as seen in **Figure 18**), a buildout of a PBL network, or a combination of both. The reallocation of curb space for a diverse array of uses enables neighborhood residents to go beyond the confines of a building or sidewalk and expands the public right-of-way.

Figure 18. Parklet

Photo of a parklet in San Francisco, CA (2021)

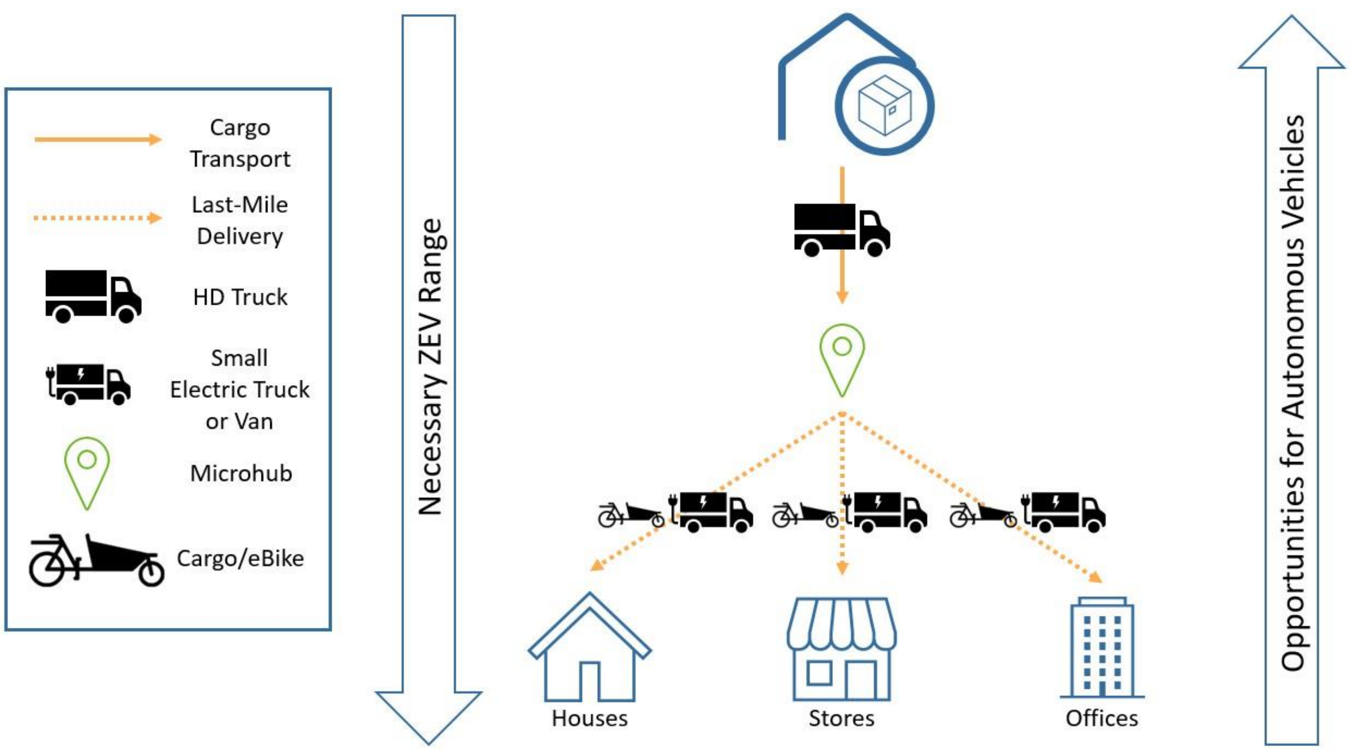
Innovations within the Zero-Emission Delivery Landscape

Digital tools for managing physical assets support broader data-driven decision-making and policy development. Curb space management providers develop and design software platforms that work for both delivery drivers and municipal staff. By gathering information about curb utilization and availability for loading zones, it brings the rapid ideation of technological advances and incorporates them into the day-to-day operations for a variety of municipal departments such as parking enforcement, engineering, transit, and economic development.

Vehicle manufacturers, technology companies, and logistics providers are developing and experimenting with a broad range of robotization, automation, and autonomous driving solutions to supplement advances on electric-drive powertrains, aiming at increasing the efficiency of transport and distribution, as seen in **Figure 19**. Tailored logistics solutions might require fit-for-purpose vehicles with the capacity to power auxiliary systems for in-vehicle cargo handling and drones. For example, fully automated cargo loading and unloading of delivery trucks could shorten the turn-around time at logistics centers. Automated parcel handling could also be conducted inside the delivery vehicle to save handling time for the driver. Multiple drones and droids could deliver goods from a centrally located delivery truck, while the driver could focus on those deliveries that still require human handling. Whereas an integrated implementation of such solutions might take a while, some elements will be deployed sooner. Companies such as Amazon, Just Eat, and Domino's are developing droids that deliver parcels and food to households fully autonomously.

Diagram of ZEV Range and Opportunities for Lightweight and Autonomous Vehicles as part of Distribution Network City regulations, such as ZE zones, bans on ICE vehicles, curbside management, and road pricing may be drivers to nudge the private sector towards cleaner and more sustainable delivery modes. To stage the process, heavy-duty trucks could transport cargo from regional distribution centers to city microhubs, from where cargo could be distributed by smaller trucks or vans to its final destinations, such as stores and households with the support of automated devices. This would enable retail and logistics companies to efficiently use shorter-range ZEVs with dedicated autonomous capabilities (like follow-me functionalities) for last mile deliveries while the performance and cost of electric-drive technologies for larger vehicles improve.

Figure 19. Diagram of ZEV Range and Opportunities for Lightweight and Autonomous Vehicles as part of Distribution Network

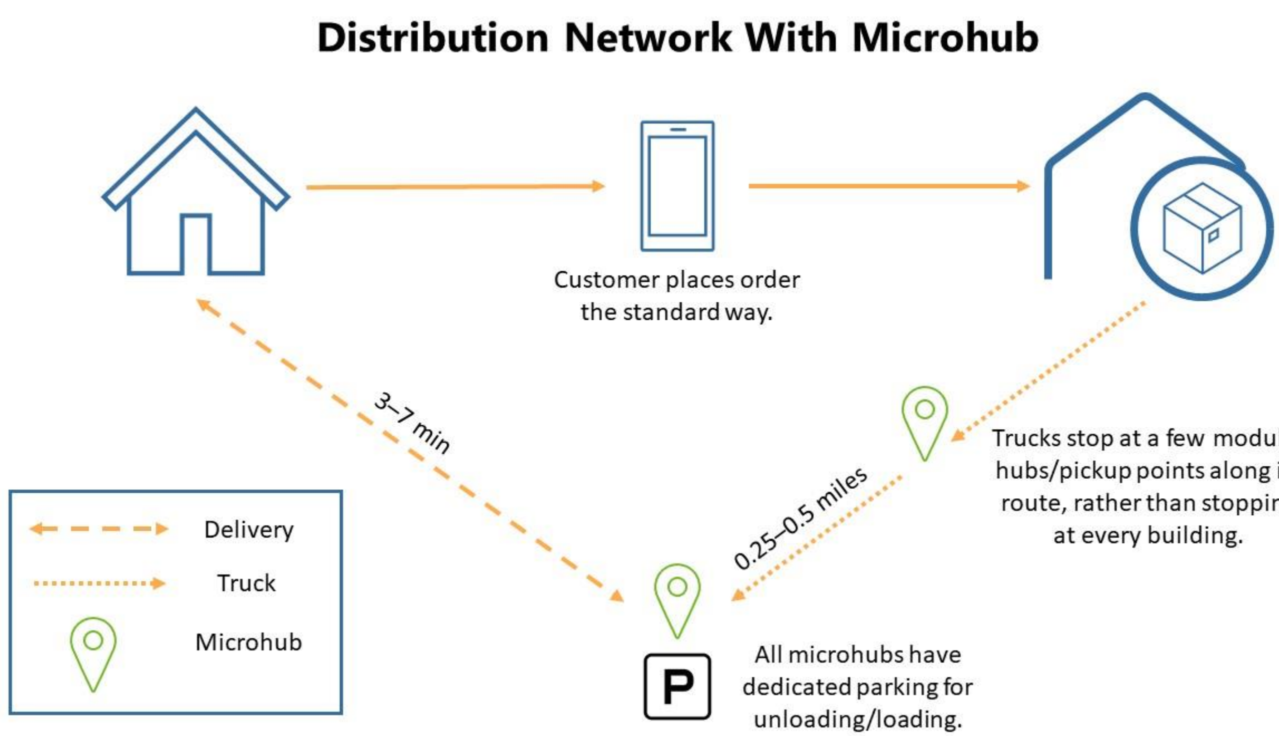


Microhubs for Delivery Staging

Microhubs is defined as a small-scale distribution center in dense urban areas (Urban Freight Lab, 2020). Microhubs emerged from the concept of "urban consolidation center" (UCC) in the 1970s, which aimed to consolidate deliveries by creating logistics centers in the heart of urban areas, where goods could theoretically be transferred and combined. However, these UCCs had the fatal fault of being too large and cumbersome; delivery times increased, and associated costs also increased. Microhubs resolve the issues faced by UCCs by serving a much smaller region; this can be as small as a city block or a neighborhood (Wouter van Heeswijk, 2019).

As shown in **Figure 20** below, microhubs for delivery placed at frequent intervals in an area will lead to more efficient routing and fewer stops, as one microhub would serve multiple residential or commercial buildings. A high density of microhubs will enable the hubs to be a three to seven-minutes away, which builds a network of distribution in dense areas of cities. Door-to-door delivery could still occur for those who need it, but the scale would be reduced. Moreover, the predictable placement of microhubs means that dedicated parking for trucks can be reserved.

Figure 20. Distribution Network with Microhub



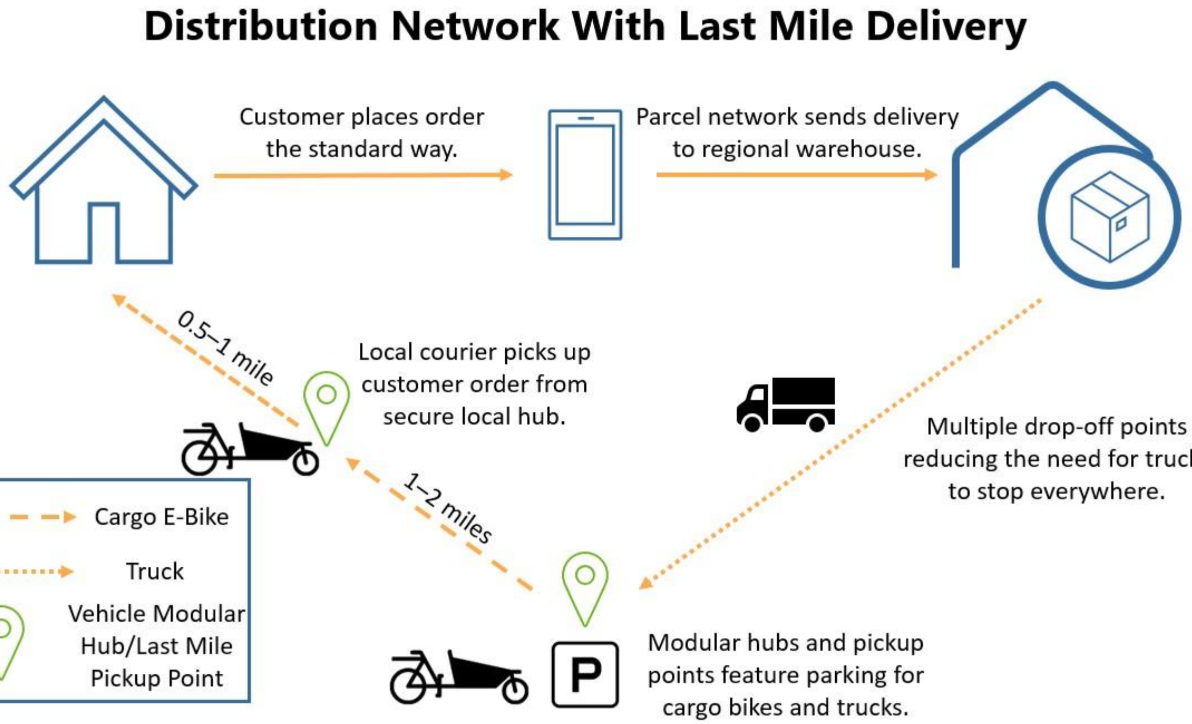
Secondly, the microhub would serve as a last mile delivery focal point. As mentioned previously, trucks would park and load goods into the locker or storage structure like **Figure 21**. A courier or e-bike operator would then pick up a set of packages and do deliveries locally. This would reduce VMT for trucks and facilitate a finetuned delivery approach; existing courier networks could be leveraged, or parcel delivery services could launch their own. With placement considerations adjacent to bike infrastructure, bike parking pod could be attached to the microhub, which would enable delivery workers to gather at the hub and charge their bikes while sorting incoming packages.

Figure 21. Amazon Locker

Photo of Amazon Locker in Santa Monica, CA

Amazon has implemented a form of the microhub concept through Amazon Hub. In a way, the Amazon Hub functions as a high-capacity post office, aided by technology and a rapid distribution network. When arriving to pick up a package, a user scans a code, which places the package into a "pickup locker" accessible only through a unique code. The Amazon Hub concept encourages flexibility while reducing package loss due to theft or human error. For general parcel delivery, similar concepts could be explored. The graphic below illustrates how this type of distribution network would function. The net benefit of this system includes reduced VMT, and improved delivery time estimates for the customer.

Figure 22. Last Mile Delivery with Microhubs



Microhubs act as smaller distribution centers and streamline complicated existing logistics network. Each microhub functions as an agglomeration of many commercial and residential units in an area, and private couriers, delivery companies and gig workers using bicycles or other forms of transportation can fill in the last gap between the microhub and the home, as seen in **Figures 20 and 22**. Parcel and goods movement companies can utilize their existing logistics resources to deliver to consolidated microhubs and utilize a dedicated fleet smaller clean vehicles for last mile delivery. In addition to microhubs, motorized electric pallets (see **Figure 23**) provide a way of delivering to dense areas, such as mixed-use buildings.

Figure 23. BrightDrop EP1 Electric Pallet

Photo credit: BrightDrop (n.d.)

The use of modular, small-scale delivery hubs scattered throughout urban areas or suburban areas can improve delivery times and simplify delivery logistics networks. Local mobility hubs with a coordination component could act as a prime example. The concept makes microhubs a local distribution node in a logistics network. Low-emissions trucks can unload in a dedicated space and store their goods in secure lockers before heading to their next destination. Further, advanced package sorting could automatically deliver and/or "send out" a delivery when requested.

Automated Cities: Autonomous Vehicles & Robotics

A popular local or last mile delivery solution being explored is automated robotic delivery. Robotic delivery is actively being researched and developed, with a new landscape of technology providers such as Nuro, Coco, and Starship. Small robots for food delivery are being tested across the country, including in Santa Monica as part of the ZE Delivery Zone pilot (see **Figure 24**). Most robotic delivery efforts have been focused on food delivery with heated and cooled components, but delivery of additional products is being investigated as well. A favored design for robotic delivery is a six-wheel design that can operate along sidewalks and pathways, though some robotic delivery vehicles currently being developed include larger autonomous vehicles that would operate on the road (Charlton, 2020).

The US Department of Transportation approved the first fully autonomous, human-free on-road delivery vehicle in 2020 (Benveniste, 2021), and as of March 2021, ten states and Washington D.C. have passed laws to allow autonomous delivery robots/vehicles to operate on sidewalks (Kingston, 2021). Companies tend to test these vehicles on college campuses, and several pilots for autonomous sidewalk delivery vehicles are underway. Current pilots and demonstrations include a human monitor. For small sidewalk delivery vehicles, a human attendant typically follows closely on a bicycle (CB Insights, 2021).

Figure 24. Coco Delivery Robot

Photo of Coco Delivery Robot in Santa Monica, CA (2021)

Delivery robot designs differ not only in product type, but also in operation. While many delivery robots rely upon human involvement for packing and loading, some have been designed to be automatically loaded, further autonomizing the process. Companies have also taken a different approach whereby a larger vehicle that operates on the road contains a small store in which people request and purchase products. Having a variety of products within a vehicle that can make multiple stops would reduce the number of return trips to the hub, further increasing efficiencies and reducing VMT (Charlton, 2020).

Autonomous delivery vehicles will be critical in last mile goods delivery and will enable companies to utilize existing storefronts and distribution centers; AVs are paired with the implementation of microhub systems. They will allow for safer and more efficient delivery and will decrease emissions, but as with all new technologies and innovations, will require comprehensive public engagement and close collaboration and partnership between the public and private sectors. Initial assessments may include a strategic review of vehicle types, but in some locations (or over time) a degree of autonomy may become preferable when appropriate.

Looking beyond AV robots for last mile delivery, autonomous driving for trucks will be implemented in phases. There are distinct levels of autonomy, where all stages up to and including Level 3 require some degree of driver engagement. At Level 4, the driver has no responsibility on certain roads (mostly highways), and at Level 5, autonomy absolves driver responsibility on all roads and in all conditions.

CONCLUSION AND NEXT STEPS

City agencies and industry must work closely together to design dynamic city curb management practices that resolve emerging freight and urban habitability trends. Cities are already working with industry to manage new technologies that have redesigned urban transportation systems. Transportation network companies such as Uber and Lyft traverse roadways widely to pick up and deliver passengers, gig delivery drivers make short-term trips, docked bikeshare stations occupy reallocated parking spaces, and shared scooters and bikes dot city sidewalks. Each of these instances required cities to carefully consider and manage how the industry partners providing technological advancements should roll out their services to residents. Similarly, the rapid redesign of freight systems through consumer behavior and technological evolution has created both a need to manage how goods are delivered to urban residents and an opportunity to create systems that efficiently share space with the community.

Leading cities have begun exploring best practices to manage freight systems and improve curb access. Building off the examples of ZE Delivery Zones in Oslo and Santa Monica, municipalities have access to lessons learned and success metrics for scaling to new markets. Complementary cargo e-bike pilots in Toronto and NYC play a large role in right-sizing fleets and creating a culture of innovation to the last mile delivery space. These examples demonstrate cities' appetites for more efficient freight systems to meet changing consumer needs while also working with industry to achieve their goals.

Recent disruptions to urban living practices make the timing to redesign and revitalize urban transportation systems advantageous. Increases in TNC rides, improved transit options, and innovative mobility solutions, such as e-bikes and scooters, all provide mobility solutions that move away from independent car ridership. This trend may reduce parking space needs and open roadways and curbsides for more efficient uses. When paired with other behavior changes such as increased instances of working from home, residential delivery options, and public repurposing of sidewalks and streets, the need for parking may further decrease while other demands for curb space continue to increase.

Collaboration is critical to ensuring that new freight industry technologies fit the needs of a region’s consumers and residents. The lessons from the real-world trends and technologies identified in this white paper led to the following recommendations for successful management of curb space and innovative technologies:

Define the space needed: Any new technologies or goods movement systems that depart from traditional practices will require physical space and access, which may take space away from or otherwise interfere with existing curb space uses. Establishing where and how new technologies will physically operate will help identify systems that will be impacted and those that will not, mitigating general concerns and identifying which stakeholder’s vehicle operators and city agencies should work with to minimize any interference. Defining the physical space will also ensure that the technologies are used as they are supposed to be and are not encroaching on others’ allocated spaces.

Define the system: As the example in NYC illustrated, a new technology or management practice requires sufficient time for local agencies to interpret how that new tech should be classified or regulated. City agencies will need to ensure that the technology is interpreted in a manner that equitably addresses concerns over safety, fairness, and equal access. The process of defining a technology or new management practice may require extensive review from multiple city agencies and therefore should be attended to as early as possible.

Establish early, ongoing communications: Defining new technologies and the space needed to operate take time to consider, certify, and zone. Industry leaders must introduce their plans to city leaders and agencies before introducing their technologies onto a city's streets and sidewalks. It is important for both sides to recognize the same potential for transformation and the improvement of residential experiences for a new technology and curbside management application to succeed. Once the process of communication and collaboration has begun and all parties share the same goals, keeping lines of communication open will support mutual interests.

Earn support of local organizations: Altering current systems with new technologies or curbside management practices is likely to directly concern or impact both residents and businesses. Successful approaches, as city leaders in Santa Monica have described, include directly addressing and working with neighborhood associations, business improvement districts, and other regional stakeholders. Ultimately, these groups represent the customers and businesses that are meant to benefit from improved freight systems, so including their opinions and addressing or mitigating their concerns will help create strong regional support.

Phase in new technologies or practices: A measured approach that phases in new systems, rather than inundating existing systems, helps identify any designs or practices that can be improved before full-scale deployments. Industry partners and city managers can share their learnings on how efficiently new systems are operating and work to ensure that small problems are managed before they become more expensive or ingrained at scale. The phased approach is also more likely to build good will with residents, provoking curiosity rather than concern. If the technology or management practice does not ultimately prove successful, a measured rollout will also help avoid stranded assets.

Though no one technology or policy solution will likely meet all the needs of freight companies and urban residents, continued innovation and collaboration between industry and municipalities will support more efficient, more equitable, and safer systems of goods movement. The path forward lies in testing and ideation of innovative concepts as part of public-private partnerships and municipalities collaborating across departments to design and implement policies that support a cleaner method of distributing goods, leveraging the curb as an asset.

REFERENCES

Baertlein, L. (2020). Yahoo! Finance. *COVID-10 Delivery Surge Strains FedEx Service, Opening Doors for UPS*. Retrieved from: https://finance.yahoo.com/news/covid-19-delivery-surge-strains-194748242.html

Benveniste, A. (2021). CNN. *Domino's is launching a pizza delivery robot car*. Retrieved from: https://www.cnn.com/2021/04/12/tech/dominos-pizza-delivery-robot/index.html

Bicycle Dutch (2019). *Finally fully open: Utrecht's huge bicycle parking garage*. Retrieved from: https://bicycledutch.wordpress.com/2019/08/20/finally-fully-open-utrechts-huge-bicycle-parking-garage/

BrightDrop (n.d.). BrightDrop EP1 Electric Pallet [Photograph]. Retrieved from: https://www.gobrightdrop.com/products/ep1

Carbon Neutral Cities Alliance (n.d.). *'Game Changers' Initiative*. Retrieved from: https://carbonneutralcities.org/what-we-do/game-changers/

CB Insights (2020). *40+ Corporations Working on Autonomous Vehicles*. Retrieved from: https://www.cbinsights.com/reports/CB-Insights_Corporations-Working-On-Autonomous-Vehicles.pdf

Charlton, A. (2020). Gearbrain. *These 7 robotic delivery companies are racing to bring shopping to your door.* Retrieved from: https://www.gearbrain.com/autonomous-food-delivery-robots-2646365636.html

City of Oakland (2020). *Oakland 2030 Equitable Climate Action Plan*. Retrieved from: https://cao-94612.s3.amazonaws.com/documents/Oakland-ECAP-07-24.pdf

City of Oslo (2016). Climate and Energy Strategy for Oslo. Retrieved from: https://www.oslo.kommune.no/getfile.php/13166797-1480690482/Content/Politics%20and%20administration/Green%20Oslo/Plans%20and%20programmes/Climate%20and%20Energy%20Strategy%20Oslo.pdf

Cuba, J. (2019). StreetsBlog NYC. *Loading Zones: DOT is Finally Taking Back Some Streets from Car Storage!* Retrieved from: https://nyc.streetsblog.org/2019/07/25/dot-is-finally-taking-back-some-streets-from-private-cars/

Curbside Cycles (2020). FedEx Cargo E-bike [Photograph]. Retrieved from: https://curbsidecycle.com/blogs/blog/fedex-bullitt-larry-harry-cargo-bike

DB Schenker (2019). *Sustainable Logistics: DB Schenker opens first low-carbon distribution terminal in Norway*. Retrieved from: https://www.dbschenker.com/de-en/about/press/corporate-news/sustainable-logistics--db-schenker-opens-first-low-carbon-distribution-terminal-in-norway-594248

Downtown Boston BID [@DTownBostonBID] (2014). Pedestrian Zone Signage in Downtown Crossing [Photograph]. Retrieved from: https://twitter.com/DTownBostonBID/status/519534500897124353

Edwards, T. (2019, March 26). ULEZ: The most radical plan you've never heard of. BBC News. https://www.bbc.com/news/uk-england-london-47638862

Etherington, D. (2019, September 3). UPS Introduces Hybrid, Long-Range Trucks that change Modes Based on Where They Are. TechCrunch. https://techcrunch.com/2019/09/03/ups-introduces-hybrid-long-range-trucks-that-change-modes-based-on-where-they-are/

European Commission (n.d.). *European Green Capital.* Retrieved from: https://ec.europa.eu/environment/europeangreencapital/index_en.htm

Fjellinjen (n.d.). *Congestion charge and environmental differentiation rates in Oslo.* Retrieved from: https://www.fjellinjen.no/private/news-archive/congestion-charge-and-environmental-differentiation-rates-in-oslo-article979-967.html

Greater London Authority. (2021). The Mayor's Ultra Low Emission Zone for London. London City Hall. https://www.london.gov.uk/what-we-do/environment/pollution-and-air-quality/mayors-ultra-low-emission-zone-london

Greenberg, J./Universal Images Group via Getty Images (n.d.). Citi Bike Station [Photograph]. Retrieved from: https://ny.curbed.com/2019/7/15/20694534/citi-bike-expansion-city-council-dot-diversity

Gothivarekar, S. (2020). Bazaarvoice. *How COVID-19 is Still Impacting Shopping Behaviors*. Retrieved from: https://www.bazaarvoice.com/blog/how-covid-19-is-still-impacting-shopping-behaviors/

Hanzlik, M. (2021). Transportation for America. *COVID and the Curb.* Retrieved from: https://t4america.org/wp-content/uploads/2021/01/COVID_and_the_Curb_final.pdf

Jacobs, J. (1961). *The Death and Life of Great American Cities.* Random House. Retrieved from: https://booksvooks.com/nonscrolablepdf/the-death-and-life-of-great-american-cities-pdf.html?page=2

Kodukula, S., Rudolph, F., Jansen, U., and Amon, E. (2018). Greenpeace*. Living. Moving. Breathing. Ranking of European Cities in Sustainable Transport.* Retrieved from: https://www.greenpeace.de/sites/www.greenpeace.de/files/publications/living.moving.breathing.20180604.pdf

Kingston, J. (2021). Axios. *Sidewalk robots get legal rights as "pedestrians".* Retrieved from: https://www.axios.com/sidewalk-robots-legal-rights-pedestrians-821614dd-c7ed-4356-ac95-ac4a9e3c7b45.html

Lee, A. (2008). The University of Melbourne. *What is the Economic Contribution of Cyclists Compared to Car Drivers in Inner Suburban Melbourne's Shopping Strips?* (Thesis). Retrieved from: http://colabradio.mit.edu/wp-content/uploads/2010/12/Final_Thesis_Alison_Lee.pdf

Los Angeles Clean Technology Incubator (LACI) (2020). *LACI Expression of Interest: Voluntary Neighborhood Zero Emissions Delivery Zone.* Retrieved from: https://laincubator.org/expression-of-interest-ze-delivery-zone/

Los Angeles Department of Transportation (2020). *LADOT to Install Food Pick-Up Parking Zones for Restaurants Affected by COVID19.* Retrieved from: https://ladot.lacity.org/sites/default/files/press-releases/ladot-to-install-food-pick-up-parking-zones-for-restaurants-affected-by-covid-19.pdf

Mai, T., Jadun, P., Logan, J., McMillan, C., Muratori, M., Steinberg, D., Vimmerstedt, L.., Jones, R., Haley, B., and Nelson, B. (2018). National Renewable Energy Laboratory. *Electrification Futures Study: Scenarios of Electric Technology Adoption and Power Consumption for the United States*. Retrieved from: https://www.nrel.gov/docs/fy18osti/71500.pdf

Manthey, N. (2021). Electrive. *MAN finds eTGM truck promising for off-peak deliveries.* Retrieved from: https://www.electrive.com/2021/01/25/man-finds-egtm-truck-promising-for-off-peak-deliveries/

Mathradas, A. (2020). Forbes. *Council Post: Covid-19 Accelerated E-Commerce Adoption: What Does It Mean for The Future?* Retrieved from: https://www.forbes.com/sites/forbesbusinesscouncil/2021/12/29/covid-19-

accelerated-e-commerce-adoption-what-does-it-mean-for-the-future/?sh=56a80f1e449d.

Moulds, J. (2017). World Economic Forum. *Oslo just decided to get rid of its parking spaces.* Retrieved from: https://www.weforum.org/agenda/2017/06/this-city-found-a-clever-way-to-get-rid-of-cars-and-it-isn-t-a-ban-09e6e018-84d0-4814-9f0e-37085eaa9218/

NBC Los Angeles (2021). *LA City Council Authorizes Loading Zones for Zero-Emission Vehicles Only*. Retrieved from: https://www.nbclosangeles.com/news/local/la-city-council-authorizes-loading-zones-for-zero-emission-vehicles-only/2627666/

New York City Department of Transportation (2021). *Neighborhood Loading Zones*. Retrieved from: https://www1.nyc.gov/html/dot/html/motorist/nlz.shtml

New York City Department of Transportation (2021). *Commercial Cargo Bicycle Pilot: A New Mode for Last Mile Deliveries in NYC Evaluation Report May 2021*. Retrieved from: https://www1.nyc.gov/html/dot/downloads/pdf/commercial-cargo-bicycle-pilot-evaluation-report.pdf

Quednau, R. (2021). Streetsblog USA. *Inside Berlin's Free Cargo-Bikeshare Program*. https://usa.streetsblog.org/2021/05/12/inside-berlins-free-cargo-bikeshare-program

San Francisco Municipal Transportation Agency (SFMTA) (2020). *Curb Management Strategy*. Retrieved from: https://www.sfmta.com/sites/default/files/reports-and-documents/2020/02/curb_management_strategy_report.pdf

Shissler, R. (2020). Cargo e-bike, Toronto [Photograph]. Retrieved from: https://www.cycleto.ca/news/benefits-cargo-bike-parcel-delivery

Schneider, T. (2021). toddwschneider.com. *Taxi and Ridehailing Usage in New York City.* Retrieved from: https://toddwschneider.com/dashboards/nyc-taxi-ridehailing-uber-lyft-data/

Schubert, C. (2021). GeekWire. *Experimental zero-emissions last-mile delivery hub launches in Seattle as a test for urban logistics*. Retrieved from: https://www.geekwire.com/2021/experimental-zero-emissions-last-mile-delivery-hub-launches-seattle-test-urban-logistics/

Selyukh, A. (2020). NPR. *Amazon Doubles Profit to $5.2 Billion as Online Shopping Spikes*. Retrieved from: https://www.npr.org/sections/coronavirus-live-updates/2020/07/30/897271729/amazon-doubles-profit-to-5-8-billion-as-online-shopping-spikes

Srivastava, A. (2019). Silicon Canals. *Meet Cargoroo: The Amsterdam startup which is the 'Uber' of electric cargo bikes!* Retrieved from: https://siliconcanals.com/news/startups/meet-cargoroo-the-amsterdam-startup-which-is-the-uber-of-electric-cargo-bikes/

Sumagaysay, L. (2020). MarketWatch. *The pandemic has more than doubled food-delivery apps' business. Now what?* Retrieved from: https://www.marketwatch.com/story/the-pandemic-has-more-than-doubled-americans-use-of-food-delivery-apps-but-that-doesnt-mean-the-companies-are-making-money-11606340169

Szarapka, S. (2017). Aerial Photography of Streets [Photograph]. https://unsplash.com/photos/L_5cz_TQWWc

Transport for London (n.d.). *ULEZ: Where and When.* Retrieved from: https://tfl.gov.uk/modes/driving/ultra-low-emission-zone/ulez-where-and-when

United States Department of Transportation. (2015). *Complete Streets*. Retrieved from: https://www.transportation.gov/mission/health/complete-streets

UnStudio (2020). *Future Mobility Hubs Shouldn't Only Focus on Transport, UNStudio Webinar Hears.* (https://www.unstudio.com/en/page/14250/future-mobility-hubs-shouldnt-only-focus-on-transport-unstudio).

UN Environment Programme (2018). *Oslo takes bold steps to reduce air pollution, improve livability*. Retrieved from:

https://www.unep.org/news-and-stories/story/oslo-takes-bold-steps-reduce-air-pollution-improve-livability

Urban Freight Lab (2020). University of Washington Supply Chain Transportation & Logistics Center. *Common MicroHub Research Project Research Scan.* Retrieved from: http://depts.washington.edu/sctlctr/sites/default/files/research_pub_files/SCTL-Microhub-Research-Scan.pdf

Victoria Transport Policy Institute (2020). *Transportation Cost and Benefit Analysis II – Parking Costs*. Retrieved from: https://vtpi.org/tca/tca0504.pdf

Wadud, Z. (2020) *An examination of the effects of ride-hailing services on airport parking demand*. Journal of Air Transport Management. Retrieved from: https://www.sciencedirect.com/science/article/pii/S0969699719302108

Ward, J., Michalek, J., Samaras, C., Azevedo, I., Henao, A., Rames, C., and Wenzel, T. (2016). iScience. *The impact of Uber and Lyft on vehicle ownership, fuel economy, and transit across U.S. cities.* Retrieved from: https://www.sciencedirect.com/science/article/pii/S2589004220311305

Wouter van Heeswijk, R. and Larsen, A. (2019). International Journal of Sustainable Transportation. *An urban consolidation center in the city of Copenhagen: A simulation study.* Retrieved from: 10.1080/15568318.2018.1503380